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Technical Report PTR-1033S-78-4 ✓
Contract No. MDA903-76-C-0241
April 1978

98-0285

AD-A134437

USE OF COMPUTER-GENERATED MOVIE MAPS TO IMPROVE TACTICAL MAP PERFORMANCE

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ACKNOWLEDGMENTS

A number of individuals have made significant contributions to the program effort described in this report. Ulf Helgesson helped in the design and construction of the Dar-El-Mara data base. Bob Goldstein of MAGI supervised the programming effort and was directly responsible for producing the computer-generated movie map. Michael Halperin, of EMET Productions, provided general support to the film and videotape production effort. Dr. Kristina Hooper, of the University of California, Santa Cruz, offered numerous valuable suggestions for designing the guided tour. The technical support of Dr. Craig Fields, ARPA/CTO Contract Monitor, is gratefully acknowledged and appreciated.

1. INTRODUCTION

1.1 Summary

Computer-generated, three-dimensional pictures provide a highly natural means of presenting map information. A sequence of computer views can be linked to provide a realistic tour, or "computer movie map", of a specific locale. A prototype computer movie map was produced for the fictitious desert town of Dar-El-Mara. An experimental study, involving 45 participants, was conducted to examine: (1) the comparative effectiveness of the computer movie map versus a conventional map in teaching the map user about Dar-El-Mara; and (2) the effect of movie map display size on performance effectiveness.

Results of the study clearly showed a substantial advantage in favor of the movie map medium. Major map performance skills were significantly enhanced compared to a baseline of conventional map performance. For example, with the movie map, errors in self-localization were reduced by factors of 6 to 30, error in spatial relations was reduced by more than half, and topographical knowledge was improved by 30%. It appeared that a large-screen projected TV display was marginally better than a small-screen TV monitor display, particularly for self-localization and topographical knowledge, but the effect was not great. The results suggest several immediate C3 applications of the computer map technology; these include: (1) locale familiarization, (2) maneuver aiding, and (3) command coordination.

1.2 Computer-Generated Movie Maps

Accurate and efficient map interpretation is essential in nearly all phases of military planning and operations. It is significant,

therefore, that many military personnel often experience difficulty using conventional map displays (Potash, 1976). Recent developments in computer-generated display systems may effectively reduce this problem by providing a three-dimensional, pictorial representation of military target and/or maneuver areas. Such representations may be either static or dynamic. In the dynamic case, computer-generated displays can essentially give the user a realistic "guided tour" of the tactical area normally covered by a conventional map. Such tours have been termed "computer movie maps".

The basic assumption underlying the computer movie map display is that dynamic movement within a geographic data base provides the viewer with "first hand" viewing experience. Unlike a conventional map, a movie map does not require the user to imagine the physical appearance of an unfamiliar place. Realistic computer-generated scenes preserve the salient features found in the actual environment.

The natural orientation of the new display technology blends consistently with classical psychological theory, which integrates perception and memory. For example, in Travers (1972), Gibson writes:

"...an illustration of how the perceptual and the memory systems are intimately related is that the little bit of the world we see in front of us is assumed to be a part of a total visual world that includes also everything we cannot see at any particular instant, including the world behind our backs. The immediate perception of the world has a continuity with the rest of the world and also a continuity with the past, which one cannot know in the immediate present except through one's memory. The memory systems and the perceptual systems are not two distinct sets of systems, but are highly dependent one upon the other".

One way in which the integration of perception and memory can occur is through a version of what is called "template matching" theory

(Neisser, 1967). Essentially, the process postulated is that traces of previous perceptual experience are not stored separately in memory, but are rather somehow consolidated into a composite trace. New experience then is evaluated and interpreted with respect to how it matches the composite trace built up through that point in time. Through the computer generation of realistic situational pictures, the user is able to integrate naturally situational information both into an immediate composite trace, and into the continuing trace of all his previous visual experience. This provides a strong framework for remembering situational elements, and for making more effective use of the display. Parenthetically, it is interesting that in their development of tests for assessing the effectiveness of relief maps, Potash, Farrell, and Jeffrey (1976) ask the user of the conventional map to select the correct geographical configuration by identifying it from a choice of several true perspective sketches.

1.3 Performance Model

The psychological processes underlying the use of computer movie maps may be clarified by a task-analytic model of tactical map performance skill. Two basic performance processes have been tentatively identified: (1) pattern recognition during landmark identification; and (2) directional inference using landmarks as cues to spatial orientation. These processes are essential to all aspects of tactical map use, since, for example, route planning and execution cannot begin until field position and orientation have been established. The objective of both computer-based and conventional maps is to provide the user with sufficient information to perform both performance subtasks.

Preliminary analysis suggests that while movie maps provide information relevant to both landmark identification and directional

inference, conventional abstract maps place the burden of landmark identification upon the user. Since the identification of geographical landmarks is essential for inferring current location, one advantage of the movie map may be the ease of self-localization it affords the user. Similarly, movie maps may also facilitate the assimilation of spatial relations by realistically portraying the landmarks used to infer directional heading. That is, if one is standing at a known location (e.g., the White House) and can identify a nearby landmark (the Washington Monument) then it becomes possible to infer orientation from this information.

Directional inference is a prerequisite to all subsequent maneuver activity. Although both conventional and movie maps provide the user with an overview of spatial relations, such information only becomes useful when the map user can also identify landmark cues present in the environment. This suggests that conventional abstract maps may short-circuit the inference process by failing to provide the user with sufficient knowledge of landmark appearance.

The dynamic quality of the movie map represents another important display dimension which may contribute to spatial-orientation. The apparent motion of the guided tour provides the viewer with an opportunity to experience movement parallax, a primary cue to depth perception. Thus, movie maps may facilitate the viewer's understanding of three-dimensional spatial relations by simulating the perceptual processes which operate during real world exploration.

In accord with the above analysis, our experimental evaluation of the movie map technique included measures of the two critical dimensions of map performance: self-localization and spatial relation (directional inference). Before describing the experimental methodology and assessment strategy in more detail, a brief account of the movie map prototype will be presented.

2. PROTOTYPE MOVIE MAP

2.1 Background

It was desired to include a representative variety of geographic and urban features in the movie map used as the experimental stimulus. The total duration of the tour (about 7-8 minutes) and the total mapped area (about 1 mile square) were decided beforehand on the basis of psychological, technical, and economic considerations. Rather than attempt to find a real place with all the desired characteristics, it was decided to produce a computer-generated tour of a realistic, albeit fictitious, middle eastern city, named by us Dar-El-Mara. The mid-eastern locale was chosen because (1) it seemed topical; and (2) the desert environment eliminated the need for including costly vegetation in the prototype computer model.

2.2 Movie Map Production

Production of the prototype movie map became a major part of the experimental process, and constituted a significant learning experience for all involved. The main features are outlined briefly below:

Data Base Design. To arrive at the basic layout of Dar-El Mara, project personnel gave a list of basic specifications (terrain features, built-up areas, number of identifiable landmarks, etc.) to an industrial designer, who returned a preliminary sketch of the locale. Several reiterations of the initial design produced the layout shown in Figure 2-1: a sea-side town, located on a cliff overlooking a bay, containing the combination of military and civilian landmarks listed in Table 2-1. The final design was constructed as an actual physical model, about four feet square, made of foam-core material. The model was used to check proportions, to specify color combinations, and to evaluate issues associated with candidate tours.

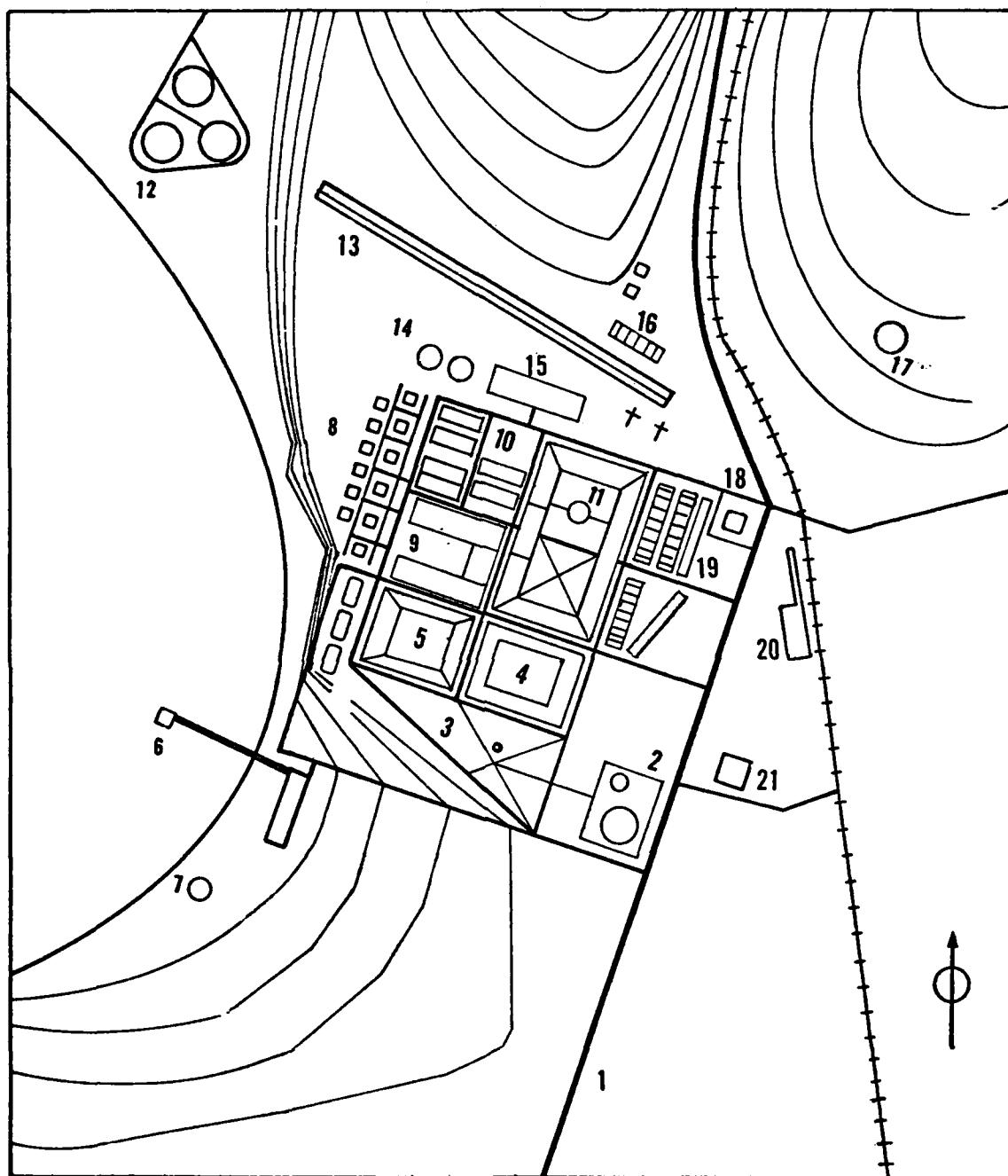


FIGURE 2-1. DAR EL MARA

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TABLE 2-1
DAR EL MARA SITE GUIDE

1. Coastal Highway
2. Golden Mosque
3. Municipal Park
4. Apartment Block
5. Office Block
6. Docking Facility
7. Lighthouse
8. Individual Housing Units
9. Shopping Plaza
10. Industrial Zone
11. Government Center
12. Oil Storage Tanks
13. Airport
14. Helipads
15. Air Terminal
16. Work Sheds
17. Water Tank
18. Gas Station
19. Market Area
20. Railroad Station
21. Railroad Warehouse

Computer Model. The display generation technique selected for the experimental study was one developed and marketed by MAGI (Mathematical Applications Group, Inc.), Elmsford, New York, under the name SynthavisionTM. This technique was chosen for the following reasons:

- (1) It can produce visual scenes of sufficient detail and realism for simulated C3 applications.
- (2) It accomodates viewer movement and object movement capabilities.
- (3) Generation costs are reasonable compared to other methods.
- (4) It is used continuously for commercial applications, thus production time is rapid and set-up costs are minimal.

The technique depends on the representation of all objects by standard geometrical shapes, i.e., shapes for which mathematical equations exist. One object can be represented by a combination of many shapes, so that this is not a severe limitation to realism. Once the objects are expressed as forms, color coded, and "anchored" mathematically in space, a light source location and observer location can be arbitrarily selected. Radiation equations are used to calculate the light from the source which would reach the observer after reflectance from the objects. These equations impart perspective and shading to the scene, increasing its realism. Each picture frame represents a fixed location of objects, observer, and light source. To make a movie tour, the location of the observer is changed from frame to frame while that of the objects remain fixed; for a completely dynamic display, both observer and objects change location.

Tour descriptions were transmitted to MAGI in the form of "director's notes" on a conventional map of Dar-El-Mara. After programming,

frames were generated at MAGI and photographed on 16-mm film. Processed film was returned to Perceptronics for review and further production.

Movie Map. An initial movie was completed which provided an extensive ground-level tour of the area. Preliminary evaluation indicated that while the MAGI technique was able to satisfactorily represent the physical structure of Dar-El-Mara's environment, a ground-level perspective was not sufficient, in itself, to effectively communicate spatial and/or geographical orientation. As a result, a new tour was developed which combined both ground-level and aerial perspectives.

The MAGI film for the revised movie map was photographically modified to include object legends overlayed on pictorial views, so as to identify significant landmarks. In addition, a narrative sound track was added to enhance user comprehension. The completed film was transferred to videotape to permit experimental viewing under realistic C3 conditions. A partial "story board", consisting of computer-generated views taken from the guided tour and the narrative associated with these views, is presented in Appendix A.

2.3 Production Rules

Production of the prototype movie map was based primarily on intuition, supplemented by considerable trial and error. Yet the resultant product seems to have turned out quite successfully, in both subjective and empirical terms. As a result, it appears worthwhile to list some of the main lessons learned from this experience, as a preliminary guide to the generation of more exact rules for future computer map production. The preliminary "injunctions" include:

- (1) Main Axes. Establish an underlying set of axes for continuous reference. In the present case, the bay, the railway line,

the northern hills and the southern hills formed the main geographical axes, and were reinforced by compass references.

- (2) Overview. Open the tour with one or more overviews, in which the main axes are related to distinguishing features in the locale. Closing the tour with an overview also seems advantageous.
- (3) Tour Route. Select a route which incorporates logical access and exit points as well as the local sites of particular interest. Direct repetition does not seem as beneficial as differing viewpoints of the same objects. Continuity and logical progression are important.
- (4) Ground-Level and Aerial. Alternate ground-level "driving" with aerial "flying". Driving should obey common vehicle rules (i.e. stay on ground, stop at corners, drive on right side, etc.). Flying need not obey such rules. For example, a particularly effective maneuver is to drive to a point, then pull directly up and back to obtain aerial view of last ground location. Landings, however, should be graduated to avoid a "bump" phenomenon.
- (5) Freeze Frames. Insert sufficient halts during both driving and flying maneuvers to accentuate key view points. These are excellent both for insertion of titles, and for the use of narrative to identify individual features, including, in particular, relations among features.
- (6) Pans. Do not overdo the use of pans. There is a tendency to attempt wide pans following a halt, particularly at ground

locations. These tend to be disorientating; the user finds it difficult to remember which direction he is facing at the end. Accordingly, reference should be made to a main axis following the pan.

- (7) Moving and Looking. Similar care must be taken when decoupling movement from viewpoint, i.e., moving one way while "looking" the other. Such movie maneuvers need to be both carefully planned and natural to a large proportion of the users in order to avoid disorientating effects. The negative effects are less if the view remains fixed on a specific point while movement occurs around that point.

3. EXPERIMENTAL EVALUATION

3.1 Overview

The objective of the present study was to assess the ability of map users to comprehend the spatial organization of Dar-El-Mara after viewing a computer-generated movie map. At issue were several related experimental questions:

- (1) Are movie maps more effective than conventional hardcopy maps?
- (2) Does the size of the movie map display contribute to performance effectiveness?
- (3) Is there any facilitating effects of mixing conventional and movie map media?
- (4) What are the effects of repeated media exposure on map performance?

A specially prepared hardcopy map of Dar-El-Mara was used to provide appropriate baseline measures of map-user performance. This map is presented as a fold-out in Appendix B.

The assessment strategy was based on a prior task analysis which had identified two major components of navigational skill: (1) self-localization; and (2) spatial relations. A measure of self-localization was obtained by simulating a field transfer task. Subjects were given photographs of computer-generated scenes and asked to specify on a conventional map the location from which this scene could be viewed. The assessment of spatial relations was based on

a non-verbal technique recently developed by Kozlowski and Bryant (1977). The subject is given a blank sheet of paper containing a specified point of origin and a list of landmark labels. His task is to place points on the paper to reflect the spatial arrangement of landmark locations. The resulting protocol is used to assess: (1) angular disparity of landmark placement; and (2) relative distance estimation. In addition to the measures described above, each subject was also given a test of topographical knowledge.

3.2 Experimental Design

Three independent groups of subjects were used to assess the effectiveness of the computer-generated movie map relative to the conventional map. These groups were:

- (1) Map-Only. Subjects in this group viewed the conventional map of Dar-el-Mara during three study sessions.
- (2) Map-Movie. Subjects in this group viewed the conventional map during an initial session, and the movie map during two subsequent sessions, each time on the large-scale display.
- (3) Movie-Only. Subjects in this group viewed the Dar-El-Mara movie map during three study sessions. These subjects were separated into two sub-groups: (1) large-screen display (LSD), and (2) small-screen display (SSD).

Table 3-1 summarizes the design features.

TABLE 3-1
EXPERIMENTAL DESIGN

<u>GROUP</u>	<u>N</u>	<u>TRIAL 1</u>	<u>TRIAL 2</u>	<u>TRIAL 3</u>
MAP-ONLY	15	MAP	MAP	MAP
MAP-MOVIE	10	MAP	MOVIE	MOVIE
MOVIE-ONLY	10	MOVIE	MOVIE	MOVIE
	10	MOVIE	MOVIE	MOVIE

3.3 Performance Measures

Three performance tests were used in conjunction with the above design; these were:

- (1) Spatial Relations, administered after each of the three study trials.
- (2) Self Localization, administered after the third study trial only.
- (3) Topographical Knowledge, administered after the third study trial only.

Each test is described briefly below.

Spatial Relations. The subject was presented with a ground-level view of Dar-El-Mara selected from the movie map. The picture was a color-xerox print in which two landmarks were labeled. The subject was instructed to imagine standing in Dar-El-Mara at the exact location and orientation specified by the picture. The subject was then given a blank sheet of 8½ X 11 paper with an "X" in the center to represent his location. The correct placement of the first landmark relative to the subject's location was indicated on the sheet. The subject's task was to indicate the relative location of seven additional landmarks. The starting point from which the subject was required to "place" each landmark varied from one trial to the next. A measure of angular disparity associated with each landmark location was obtained by comparing the observed angle of landmark location with the actual angle as determined from a map of Dar-El-Mara. In addition, the distance from the point of origin ("X") to each landmark placement was measured in

millimeters. The distance accuracy of each estimate was determined by comparing it with the actual distance on a similarly-scaled map.

Self-Localization. Photographs of computer-generated scenes were used to simulate a landmark recognition task. The subject was given a conventional map of Dar-El-Mara to which a piece of tracing paper was attached. The instructions were to indicate the point on the map from which each photograph was taken and to use an arrow to indicate the direction in which the photographer was facing. Eight photographs were viewed by each subject. The location error associated with each landmark placement was calculated by measuring the difference between the actual photograph location and the location indicated by the subject (in millimeters). Orientation disparity was measured by computing the difference between the actual direction of the photograph and the direction indicated by the subject (in degrees).

Topographical Knowledge. The subject was provided with a list of 30 natural or man-made features of Dar-El-Mara. In addition, he was given a randomly-ordered set of written descriptions associated with specific locations. His task was to match each written description with its corresponding geographical feature. A total of 16 descriptions were used.

3.4 Experimental Procedure

Prior to viewing either the conventional or movie map display, subjects were told to expect a subsequent test of geographical knowledge. Each movie or map study session lasted for 7 minutes and was followed immediately by a test of spatial orientation.

The computer movie map was stored in video cassette form and was run on a JVC Model CR-60600 cassette recorder. The large-screen movie map display was produced by an Advent 1000A Videobeam TV projector on a seven-foot diagonal screen. The small-screen display was produced by a Toshiba color television with a 9-inch diagonal screen. The viewing angles for the small and large screen display were equated; that is, the small-screen display, placed about two feet away, subtended the same visual angle as the large-screen display, placed about nine feet away.

A total of 45 male and female college students served as experimental subjects. All were paid to participate.

3.5 Results and Discussion

The test data are summarized in Appendix C, Tables C-1 through C-4. Experimental comparisons were performed separately for each of the issues under investigation. In all cases, a nonparametric analysis was used to compare differences among groups (Kruskal-Wallis one-way analysis of variance by ranks). The following discussion is organized by major experimental issue.

Large-Screen Versus Small-Screen Movie Map. Display size appeared to have a marginal, but consistent effect on movie map effectiveness. Large-screen display produced superior performance on four of five test measures. Two of these differences were statistically significant; namely: large-screen subjects were significantly better, at estimating landmark location in the test of self-localization (Table C-3 $H(1) = 5.71$, $p < .02$). Performance on the orientation portion of the self-localization test (Table C-3), and on the orientation portion of the spatial relations test (Table C-1), also favored the large-screen map viewers, but the differences were not statistically significant.

Movie Maps vs. Conventional Maps. An overall comparison among the experimental groups indicates that computer movie maps are clearly superior to conventional hardcopy displays. Movie map subjects performed significantly better on virtually every test measure. The difference was particularly striking with regard to spatial relations. Figure 3-1 shows the average orientation error for the three main groups¹, taken over the three test trials. By the second trial, Movie-Only viewers are making less than one-half the orientation error of conventional map users. Summed over all trials, movie map subjects were able to estimate landmark location with significantly more accuracy than conventional map users, $H(2) = 6.05$, $p < .05$.

Performance on the self-localization task (Table C-3) was also markedly better for movie maps. Table 3-2 following summarizes the relevant test scores. Movie map subjects were significantly more accurate in their location placement, $H(2) = 24.52$, $p < .01$, as well as in their orientation estimates, $H(2) = 24.75$, $p < .01$. Large-screen viewers achieved a six-fold reduction in location error over conventional map viewers, and nearly a thirty-fold reduction in orientation error. In fact, the LSD movie map subjects show virtually no orientation error at all, compared to an average 36.7° error for the conventional map subjects.

Finally, the test of topographical knowledge (Table C-4) also reflected a significant difference in favor of movie map subjects, $H(2) = 8.64$, $p < .02$. Large-screen viewers achieved an average test score of nearly 89%, an improvement of 30% over the 68% test score of conventional map users.

¹ Large-screen viewers are used to represent the Movie Only group, because they showed the consistently best performance.

ORIENTATION
ERROR (DEGREES)

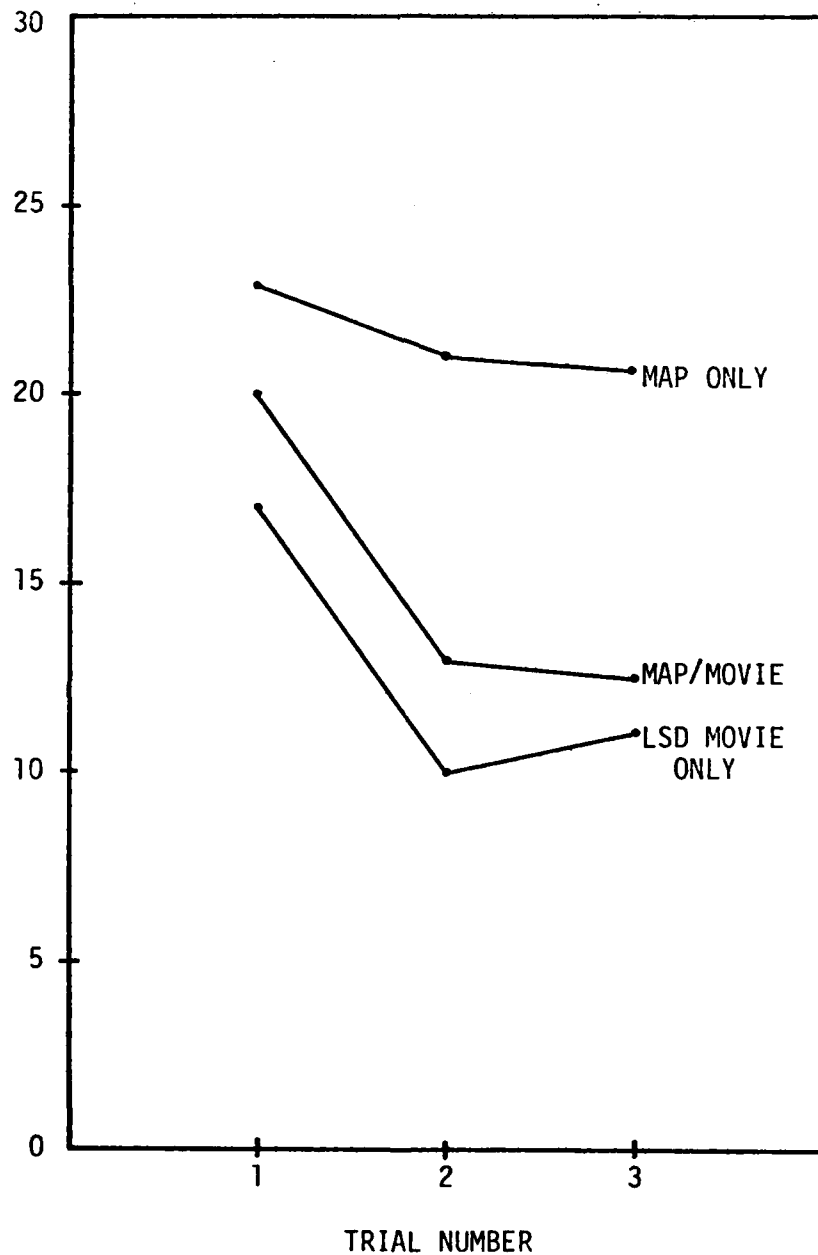


FIGURE 3-1
PERFORMANCE ON THE SPATIAL
RELATIONS TEST AS A FUNCTION
OF GROUP AND TRIAL

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TABLE 3-2
PERFORMANCE ON THE SELF-LOCALIZATION TEST

<u>GROUP</u>	<u>LOCATION ERROR (MM)</u>	<u>ORIENTATION ERROR (°)</u>
Map Only	31.8	36.7
Map/Movie	8.1	5.3
LSD Movie Only	5.2	1.3

TABLE 3-3
INCIDENCE OF COMPLETE DISORIENTATION
ON THE SPATIAL RELATIONS TASK

<u>GROUP</u>	<u>TRIAL 1</u>	<u>TRIAL 2</u>	<u>TRIAL 3</u>	<u>TOTAL</u>	<u>% SUBJECTS</u>
Map Only	1	2	8	11	33
Map/Movie	0	0	1	1	10
SSD Movie Only	0	4	0	4	20
LSD Movie Only	1	0	0	1	10

Table 3-3 provides further insight into the reasons for movie map superiority. This table summarizes the incidences of trial errors greater than 90° in the orientation portion of the spatial relations test. A subject who had a mean error score for a trial in excess of 90° was presumed to be totally disoriented with regard to a specified location. These data were not included in the foregoing analyses. However, it is interesting to note that 11 instances of disorientation, involving 33% of the subject group, were recorded for the Map-Only condition, while just one instance of disorientation, involving just 10% of the group, was recorded in both large-screen movie map conditions. The small-screen movie map produced an intermediate number of disorientations, but was still substantially below the conventional map mode.

Map and Movie. There appeared to be no facilitating effect of using conventional map presentation to precede movie map presentation. On the contrary, the group which received both forms of presentation performed, on the whole, worse than the group which received the corresponding large-screen movie map only.

Practice Effects. The effect of repeated trials could be observed only for the test of spatial relations. On the distance estimation part of this test, no group appeared to improve with practice. On the orientation estimation part of the test (Figure 3-1) there was a clear separation between the conventional map viewers and the computer movie map viewers. All groups performed nearly the same on the first trial. Conventional map viewers remained at about their initial performance level for the subsequent trials, while movie map viewers improved markedly. For the movie map viewers, it appeared that there was little or no further improvement after two study sessions.

4. CONCLUSIONS

The results of the present study suggest that computer movie maps may effectively overcome many of the problems associated with using conventional map products. It appears that the "sense of place" imparted by the movie map is significantly better than that imparted by the conventional map. This was manifested in several ways during the present study. Performance with the movie map was significantly better than with a conventional map for two key performance measures: self localization and spatial relations. Movie map users seemed to learn more about the locale on repeated exposure, while repeated study of the conventional map did not produce a significant learning effect. In addition, movie map users by-and-large avoided the frequent disorientations characteristic of conventional map use. These results indicate that the movie map concept will significantly improve map-to-field transfer.

One of the major obstacles faced by the military map user is the problem of visualizing an unfamiliar locale. Existing hardcopy maps offer the user no way to visually "preview" his destination. Computer generated scenes, on the other hand, are specifically designed to aid visualization and to provide the user with "first hand" spatial knowledge prior to direct perceptual experience. The quasi-realistic scenes produced by the computer may actually be preferable to a photographic medium for portraying spatial relations and landmark appearances. Photographic representations are often cluttered with extraneous features that complicate the recognition of geographical patterns. The simplified computer-generated image can preserve salient terrain features and simultaneously convey the detail necessary to insure landmark identification. Exactly which features and details must be emphasized in particular scenes will probably have to be determined first on a case-by-case basis, and then in accord with empirically derived rules.

Large screen movie map display seemed marginally better than small-screen display in the present study. However, this effect may have been due to the purposefully great disparity between the 7-foot diagonal advent projection screen and the 9-inch diagonal TV monitor. If the computer-generated image were shown on a somewhat larger monitor the difference in performance would probably be less. Or, if a locale were learned using an optimal large-screen display, subsequent reference to a small-screen display would probably not be detrimental. The above considerations suggest several immediate C3 applications for computer movie map technology; these are described briefly below.

Locale Familiarization. Certain military operations require that personnel gain first hand knowledge of a locale prior to their actual arrival. Commandos, for example, are expected to recognize landmark features at first glance and follow a preplanned route without hesitation. Under these circumstances, traditional training with standard hardcopy maps would be totally inadequate. In fact, such groups actually use full-scale or reduced-scale mock-ups to achieve three-dimensional visualization. Computer-generated movie maps are ideally suited to provide in-depth instruction by realistically portraying access routes and landmark appearances from both ground-level and aerial perspectives. This "guided tour" approach enables the viewer to actually preview the route he will follow and encode it in visual memory. As a familiarization procedure, the movie map provides fast and effective geographical instruction.

Maneuver Aiding. Portable movie map display units may serve as maneuver aids during military field operations. Since the size of the movie map was not primarily responsible for the observed performance improvement, small screen displays can be fitted to existing ground/air transportation. These units could provide the user with selective access to movie map information. The difficulties associated with self-

localization and topographic map interpretation would be largely eliminated by viewing realistic scenes overlaid with symbols and legends to show tactical and intelligence information. This conclusion is supported by the present findings which indicate that movie map displays effectively improve basic maneuver skills.

C3 Coordination. At present, standard topographic maps are widely used to communicate tactical information in military planning and operations. The advent of new movie map technology will facilitate the communication of geographical information by providing users with a realistic, easy-to-comprehend situation display. For example, if a message sender and a message receiver both have access to explicit visual information concerning the receiver's environment, then decision making at the C3 level and task execution at the field level will both be enhanced. The fidelity of communication between C3 personnel and lower level field units represents a major applications area where new display technology can have a strong impact.

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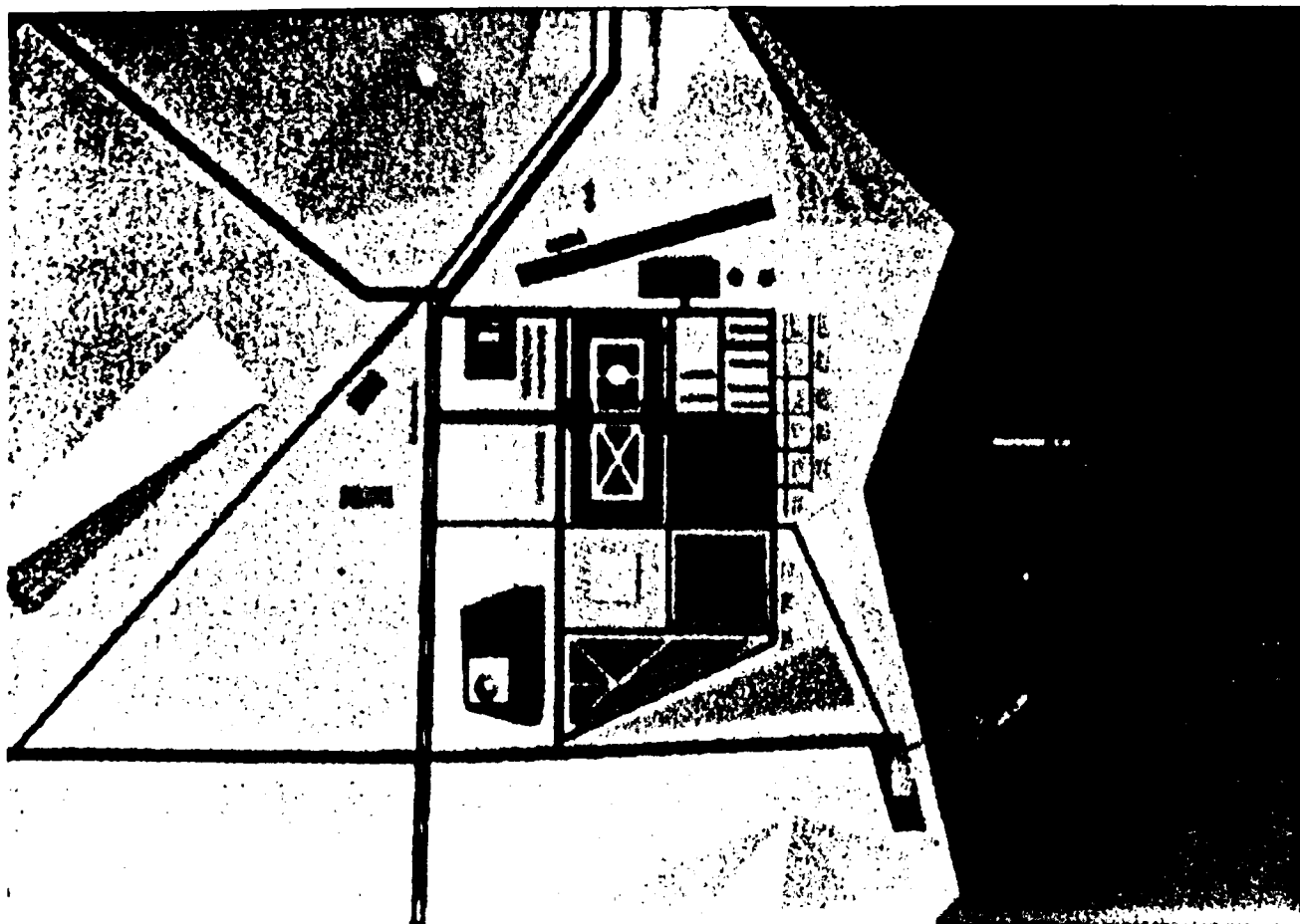
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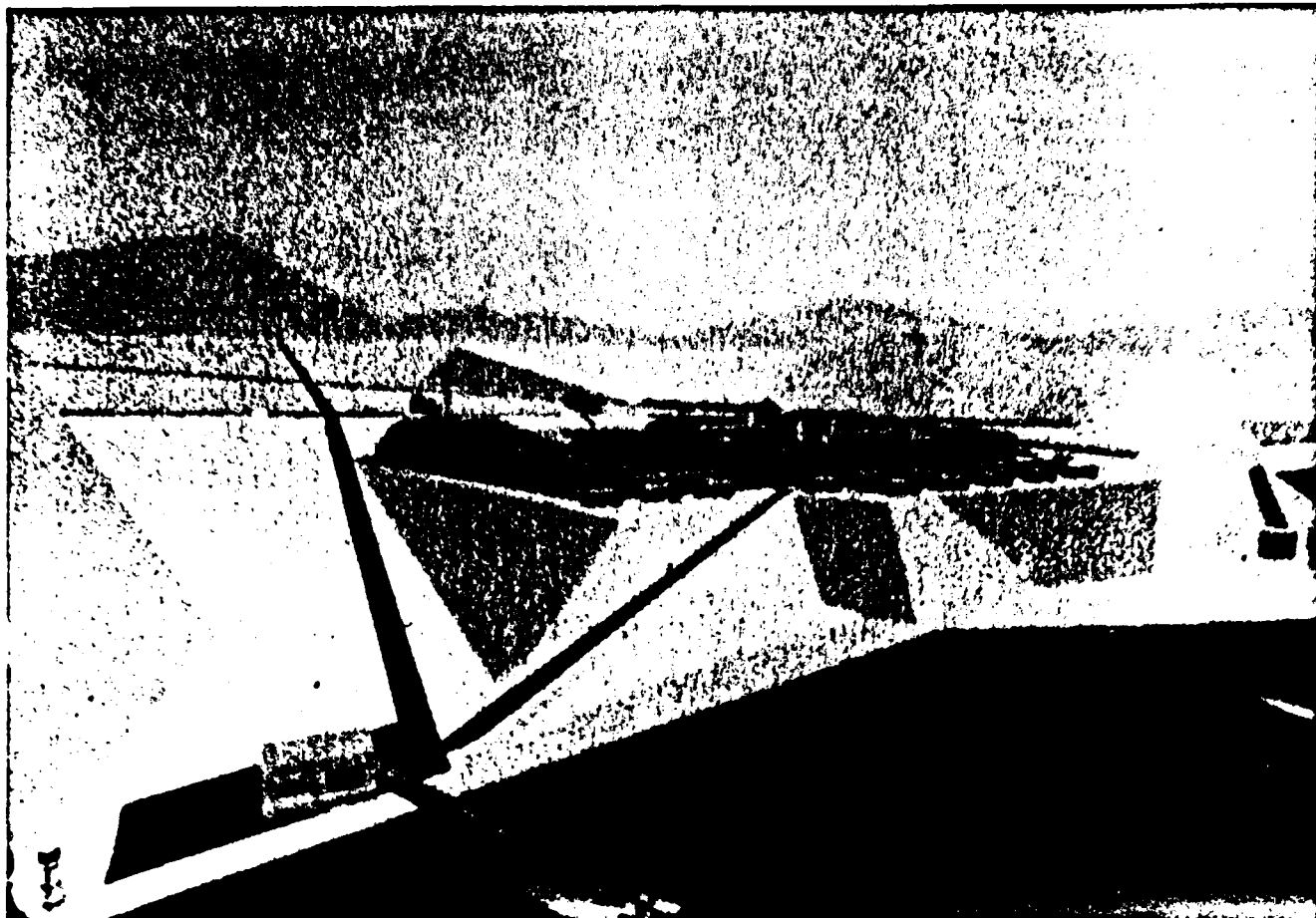
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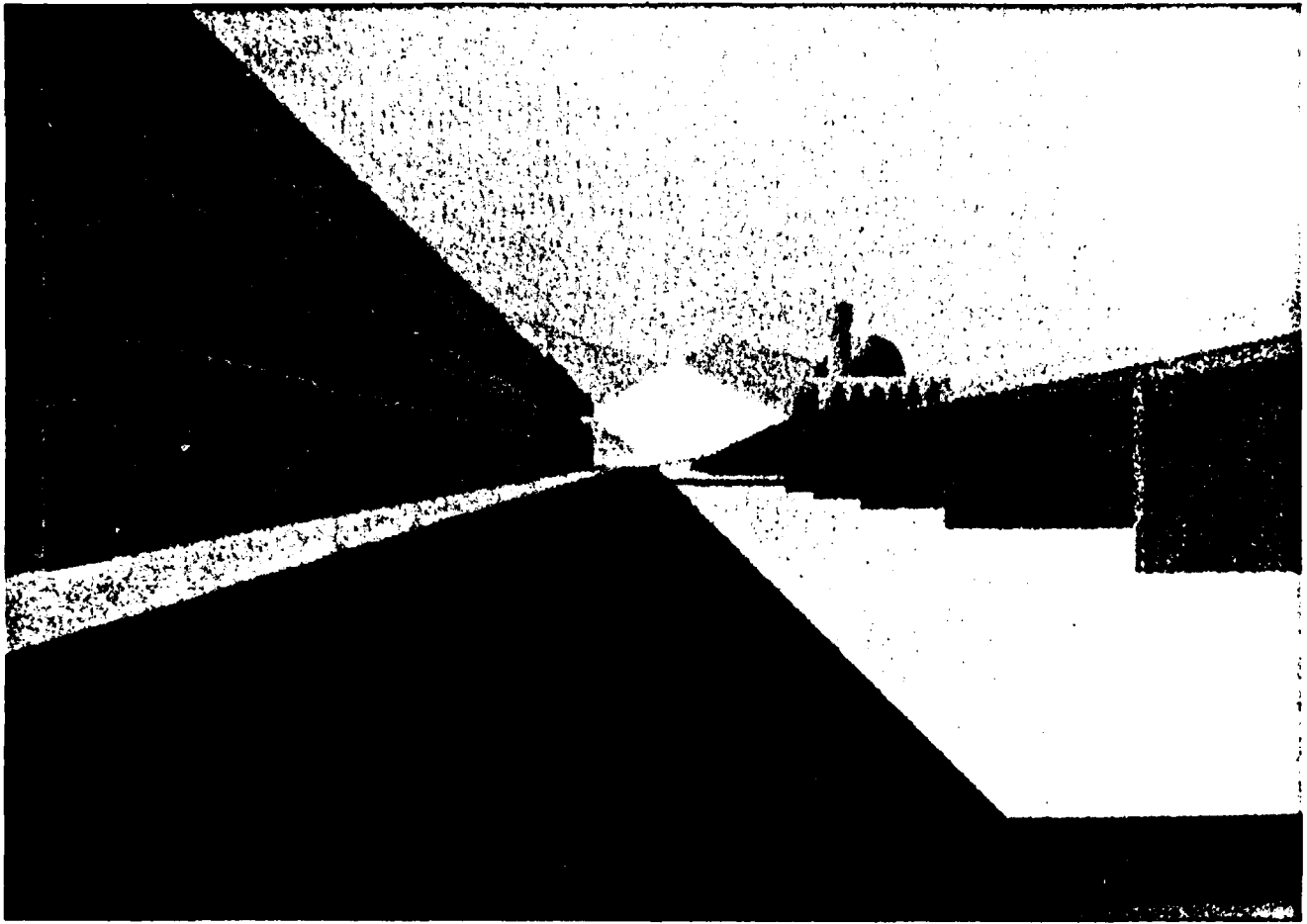
APPENDIX A
MOVIE MAP OF DAR-EL-MARA



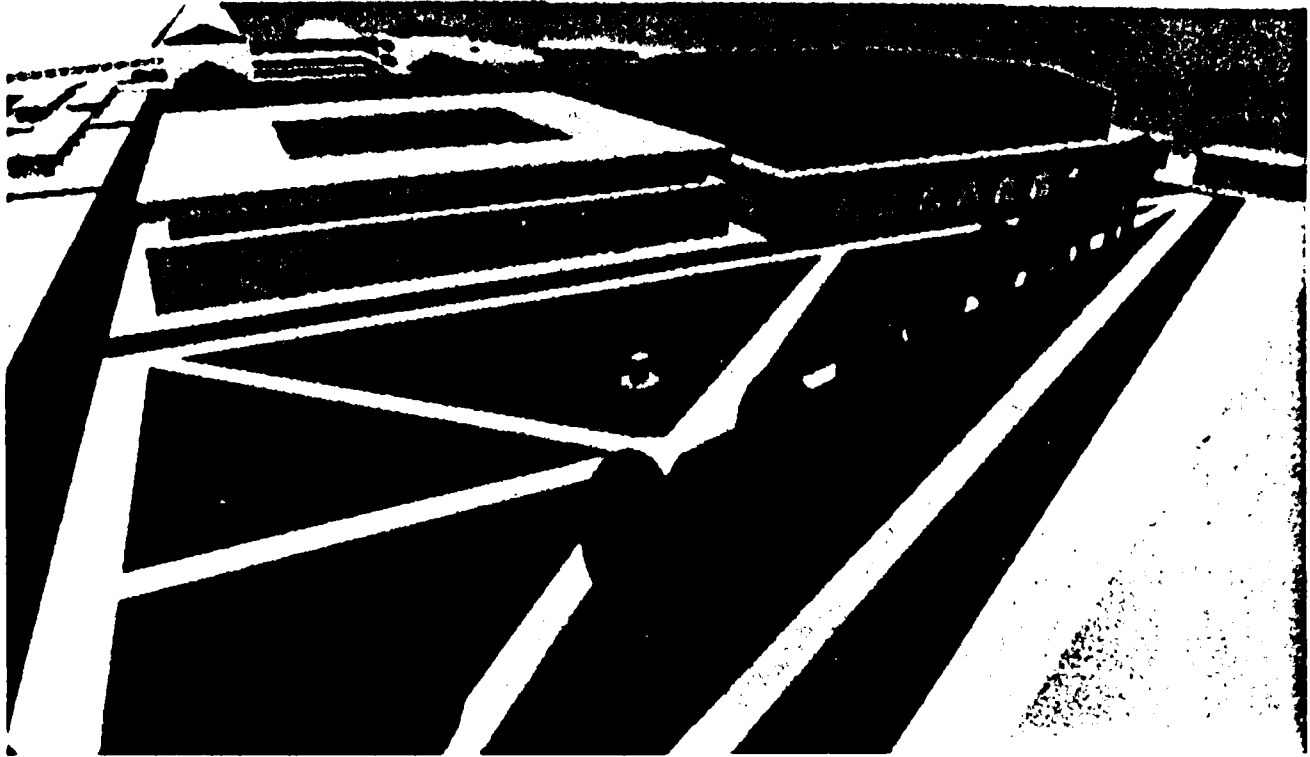
This is the seaside town of DAR-EL-MARA. DAR-EL-MARA is an industrial and military center for the coastal region. Situated on a desert plateau, the town is bounded on the east by MARA BAY -- and on the west by the MAIN COASTAL HIGHWAY. It is served by a RAILROAD LINE which roughly parallels the highway. At the north end of town is an AIRPORT area. DOCKING FACILITIES lie to the south and extend into the bay. Isolated hills arise north and south.



As we move out over the bay we see the city from the eastern vantage point. Steep cliffs rise from the beach to the level of the town. Dock Road leads from the main highway to the docking facility. Cliffside Road goes from the docking facility up the sea cliffs into town. Note the surrounding topography of flat terrain stretching toward the coastal mountain range.

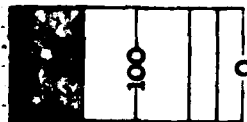


Looking south, past the market stalls, toward the Golden Mosque, we see the Government Complex to our left, behind it is the Housing Block, the Southern Hills in the direct background.

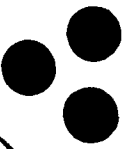


Looking over the Park with its Monument to the Fallen Heroes in the center, we see the Housing Block to the left and the the Office Complex to the right.

APPENDIX B
MAP OF DAR-EL-MARA



OIL STORAGE TANKS



AIRPORT



WORK SHEDS



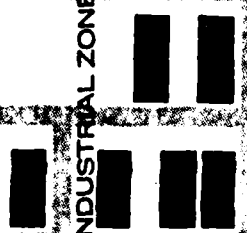
HELIPADS



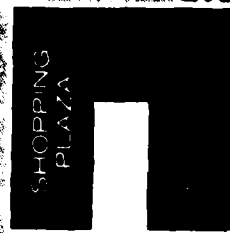
INDIVIDUAL HOUSING UNITS



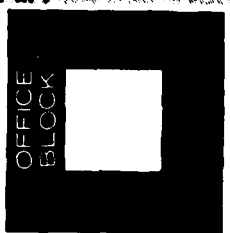
INDUSTRIAL ZONE



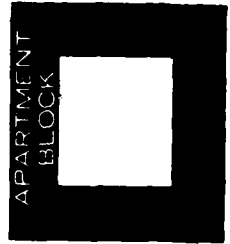
SHOPPING PLAZA



OFFICE BLOCK



APARTMENT BLOCK



MUSQUE ROAD

MUNICIPAL PARK

PARK ROAD

CLIFFSIDE ROAD

MARA BAY



DOCKING FACILITY



RAILROAD



RAILROAD STATION



RAILROAD WAREHOUSE

TOWN ROAD

MARKET AREA

GAS STATION



CENTER ROAD

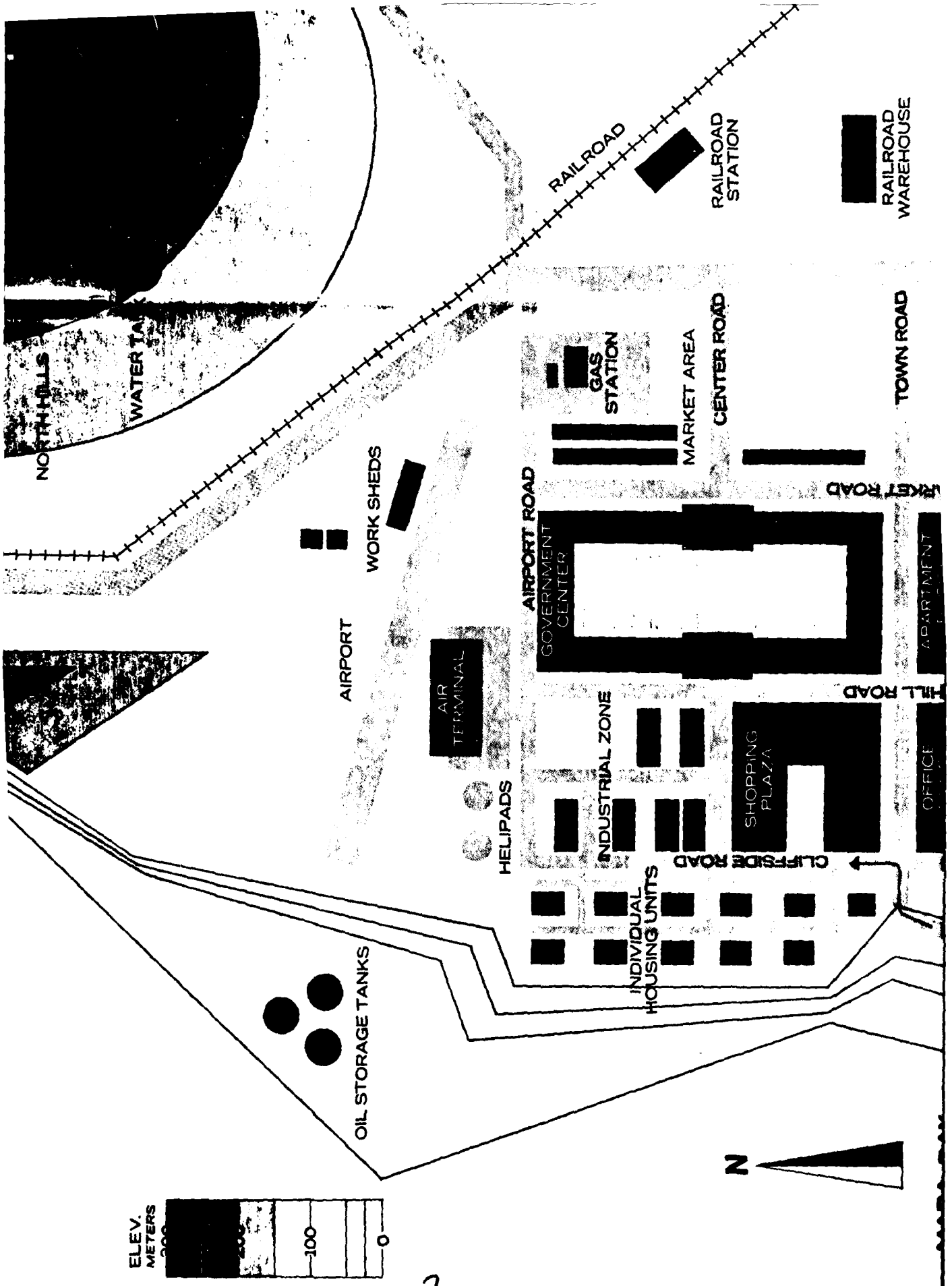


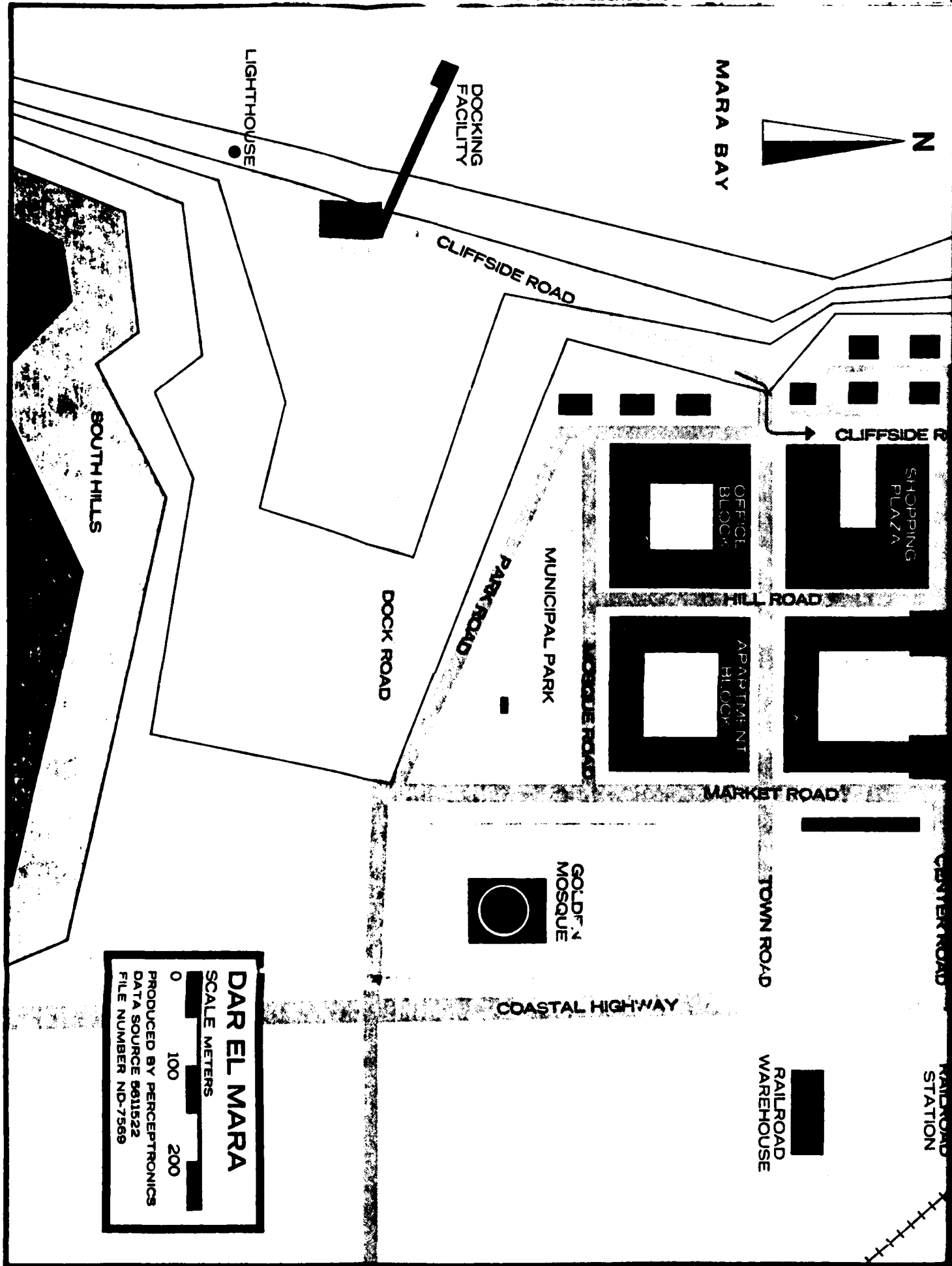
MARKET ROAD

GOLDEN MOSQUE



COASTAL HIGHWAY





APPENDIX C
EXPERIMENTAL RESULTS

TABLE C-1

SPATIAL RELATIONS: ESTIMATION OF RELATIVE ORIENTATION ($^{\circ}$)

GROUP	N	ERROR ($^{\circ}$)		
		TRIAL 1	TRIAL 2	TRIAL 3
MAP ONLY	15	22.8	21.0	20.6
MAP-MOVIE	10	19.7	13.2	12.6
MOVIE ONLY				
SMALL SCREEN	10	17.0	21.8	14.1
LARGE SCREEN	10	17.0	10.3	11.2

TABLE C-2

SPATIAL RELATIONS: ESTIMATION OF RELATIVE DISTANCE

GROUP	N	ERROR (MM)		
		TRIAL 1	TRIAL 2	TRIAL 3
MAP ONLY	15	20.74	22.30	25.40
MAP-MOVIE	10	17.73	19.19	22.29
MOVIE ONLY				
SMALL SCREEN	10	26.89	28.27	20.50
LARGE SCREEN	10	24.60	33.28	29.55

TABLE C-3

SELF LOCALIZATION: ESTIMATION OF LOCATION AND ORIENTATION

GROUP	N	LOCATION ERROR (MM)	ORIENTATION DISPARITY (°)
MAP ONLY	15	31.8	36.7
MAP-MOVIE	10	8.1	5.3
MOVIE ONLY			
SMALL SCREEN	10	11.0	10.3
LARGE SCREEN	10	5.2	1.3

TABLE C-4
TOPOGRAPHICAL KNOWLEDGE

GROUP	N	MEAN PERCENT CORRECT
MAP ONLY	15	68.1
MAP-MOVIE	10	73.2
MOVIE ONLY		
SMALL SCREEN	10	73.8
LARGE SCREEN	10	88.8